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CATHODOLUMINESCENT SCREEN WITH A COLUMNAR STRUCTURE, AND THE METHOD FOR ITS PREPARATION

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FIELD OF THE INVENTION

The present invention relates to the area of electronic materials and to microelectronics, including vacuum microelectronics, in particular to devices based on field emission, such as field-emission displays, vacuum fluorescent displays, cathodeluminescent lamps, etc.

PRIOR ART

The existing luminescent screens are produced, as a rule, in the shape of crystalline films that are prepared, for example, by deposition from a vapor phase onto smooth, for example, glass substrate.

For the deposition, techniques of evaporation of materials in vacuum, of sublimation, of chemical transport, of cathode sputtering, etc, are used.

In all the techniques, the nucleation of the crystalline luminescent materials (phosphors) occurs in a non-controlling manner, homogenously or heterogeneously, on a smooth structure-less substrate . At that case, the phosphors are usually a collection of tiny (micron and/or submicron) crystalline grains, usually isometric, approximately spherical shape superposed one onto another (Fig. 1). In such a system, the light generated in a crystalline grain (i.e., designated by a cross) is repeatedly scattered in the labyrinth of surrounding phosphor grains. This phenomenon deteriorates the resolution of the screen.

One more problem relates to the fact that in the film screen, consisting of the crystalline grains, do not all the space is filled by the phosphor. This decreases the effectivity of the screen and deteriorates its thermo- and electroconductivity.

In addition, such screens have a bad adgesion to substrates because the approximately-spherical crystalline grains have only point contacts with the substrates.

In the patent [1], single-crystalline (plate-like or epitaxial-layer) materials are used as phosphors. This improves reproducibility of characteristics of the screen and increases its effectivity (the ratio of the light energy to the energy expended for the light excitation). However, at such a case, the emitting light propagates along the plate (or along the epitaxial layer) of the phosphor; this deteriorates the resolution and the effectivity of the screen.

Another patent [2] supposes localized deposition of a phosphor from a diluted solution or suspension by spinning into holes, side walls of the holes being metallized in order to exclude penetration of the light into neighbor areas of the luminescent scren. However, at this case,

contrast of the image is increased for only 50%; in other words, scattering of the light along the luminescent screen is not excluded.

These drawbacks can be eliminated if the luminescent screen is made of columnar crystallites that have elongated shape whose elongation direction is approximately perpendicular to the plane of the screen. Such an idea is realized in the design described in the patent [3]. At such a case the light excitated at columnar crystallites of the phosphor propagates in the elongation direction of the crystallites, the crystallites being acting as light-guides. However, the method for preparation of such screens by melt crystallization is not suitable for many practically-important cases, e.g., for thin (0.1 - 1 micrometer thickness) flat luminescent screen used in field-emission displays.

In the patent [4], a screen with columnar crystals has been proposed where an insert of non-luminous black material adjacent to the columnar crystals was placed. Such an insert is able to increase an image contrast of the columns that are directly adjacent to the insert, while other columns that are not adjacent (are not contacted) to the insert are not able to increase their contrast. In addition, patent [4] does not give a method for preparation of such a screen.

In this invention, a more optimized design of the screen is proposed. In addition, a technology for preparation of the screen is proposed.

SUMMARY OF THE INVENTION

A screen with columnar structure is proposed where each column is surrounded by a gap coaxial to the column, the gaps are filled by an electroconductive non-light-emitting medium. Outer butt-ends of the columns are coated by a light-emitting luminescent layer, thickness of the layer being smaller than height of the columns for at least one order of magnitude. The luminescent layer can be epitaxial in respect to the columns.

A method for preparation of the luminscent screens is proposed in this invention, too. The method consists in vapor deposition of the luminescent material where an intermediate substance, that is other than the luminescent material and that forms a liquid phase at the crystallization temperature, is firstly deposited on the substrate. After that, the luminescent material is deposited on such a substrate. Thickness of the intermediate substance is more than 10 nanometers and smaller than 1 micrometer. The liquid phase is formed at a contact interaction of the intermediate substance with the substrate.

The intermediate substance is formed by more than one chemical elements. At least one of the chemical element is operating as an luminescent activator or co-activator. The activator or co-activator is introduced into the luminescent material by means of ion implantation.

A microrelief of inhomogenities in structure and/or chemical composition is created on the substrate, the inhomogenities being of regular character, in particular, of crystallographically-symmetric character.

The luminescent material is coated by a thin layer of a material that is transparent for electrons. In particular, diamond or diamond-like material serve as the transparent material.

A BRIEF DESCRIPTION OF THE FIGURES

Fig. 1. A scheme of a standard cathodoluminescent screen that is formed by a film of approximately isometric crystalline grain.

Fig.2. A scheme of a cathodoluminescent screen formed by a film, that consists of columns approximately perpendicular to substrate.

Fig. 3. A scheme of propagation of light beams in the film shown in Fig. 2.

Fig. 4. A SEM micrograph of a cleavage cross-section of a continuous film consisting of the columns.

Fig. 5. A scheme of the cathodoluminescent screen with columnar structure that is bombarded by electrons. The shaded upper parts of the columns show level to which the electrons penetrate and where the light is excited.

Fig. 6. A scheme of the cathodoluminescent screen. The upper butt-ends of the screen are coated by a light-emitting luminescent layer.

Fig. 7. A scheme of the cathodoluminescent screen formed of columns with gaps between them.

Fig. 8. A SEM micrograph of the film that consists of columns with gaps between them (top view). The mosaic structure of the screen is seen.

Fig. 9. A scheme of the cathodoluminescent screen shown in Figs. 7 and 8. The gaps are filled with an electroconductive non-emitting medium.

BEST VERSION FOR THE REALIZATION OF THE INVENTION

The cathodoluminescent screen with columnar structure, as it was proposed at the prior art, is illustrated in Figs. 2 and 3.

The cathodoluminescent screen, as it is proposed here, is illustrated in Figs. 4 to 9.

Typical height of the columns, as it is shown in Fig. 4, is about 5 micrometers. Typical height-to-diameter ratio of the columns ranges from 1:1 to 100:1.

An accelerated electron beam from a flat cathode, as it is usually considered in field-emission displays, is incident on the screen and penetrates into a surface layer (Fig. 5). At typical acceleration voltages of the field-emission displays (for example, 1 to 3 kV) the penetration thickness is about 100 nanometers (shown schematically in Fig. 5 as a shadowed layer). Accordingly, it is proposed to implement the screen as a columnar structure coated by a light-emitting luminescent layer (shown in Fig. 6).

The columns are surrounded by gaps ("trenches") coaxial to the columns. An elongated cross-section scheme of the columnar structure is shown in Fig. 7. A corresponding scanning electron micrograph of the screen (top-view) is shown in Fig. 8. As is seen, the columns are

surrounded by gaps ("trenches"). The gaps are filled by an electroconductive non-light-emitting medium has the coefficient of light absorption in respect to the emitting light more than 20%. A scheme of the filled screen is shown in Fig. 9. The filling ensures a conductivity of the screen and, in such a way, excludes charging phenomena when the luminescent screen is working in a cathodoluminescent mode.

These screens are featured by some advantages, especially in respect to low-voltage field-emission displays.

1. By a high light and energetic output that is caused by its design. Owing to the total internal reflection from the walls of the columns, a light-guide effect takes place: the light propagates preferentially along the columns, do not passing beyond columns and do not passing into neighbour columns.

2. By a low light scattering during the light propagation along the columns. This determines a high resolution of the design. It is equal to the number of the light-emitting components per a length unit.

3. By a high adgesion to the transparent substrate, to which the columns are fixed by their butt-ends, i.e., the light-emitting components contact to the substrate by a large area. This is especially important for diode-type field-emission displays where large gradients of the electric field are able to break screen particles off the substrate.

The advantages of the cathodoluminescent screens having the columnar structure are realized here by a proposed technology for their production. The technology is based on chemical or physical vapor deposition, a participation of a liquid phase in the deposition process being of principal importance. An effectivity of the technology is illustrated in Fig. 4 where the columnar structure of the luminescent material cadmium sulphide is shown.

It is to underline principal idea of the proposed design of the cathodoluminscent screen: the propagation direction of light in each columnar component is paraxial (parallel) to the direction of the primary electron beam, that excites the light (see Fig. 3), whereas in the known (standard) screens, formed by superposition of approximately-isometric grains, the light excited by the cathodoluminescence can propagate not only paraxially with the electron beam but also perpendicularly to it, or in any arbitrary direction in respect to the electron beam (see Fig. 1).

As the design of the columnar screen was realized and used in concrete electron devices, some not-evident its advantages were found.

(a) Luminescence brightness of different grains (columns in this case) becomes more uniform. In the standard cathodoluminescent screens, the brightness of various grains differs significantly (up to 50% at distances 25-30 micrometers) due to differences in sizes of emitting grains; this deteriorates transfer and fixation of qualitative images.

(b) Electrical and heat power dissipation by the columnar phosphors increases significantly (5 to 10 times) in comparison with the standard cathodoluminescent screens.

(c) The "burning out" of the columnar screens at an unexpected switching off the electron beam scanning is practically eliminated. In the standard cathodoluminescent screens the power sufficient for irreversable burning out of the screens is usually 0.1 W/element (here the element is an image element, i.e., a pixel), whereas preliminary testings of the proposed columnar screen indicate to increase of the parameter up to 1 W/element (here the element is a column).

(d) The background image contrast at an illumination with intensive light sources (sun, electric lamp, etc) is increased. Standard cathodoluminescent screens have the contrast value $\boldsymbol{k} = b_{image}/b < 5$, where b is the brightness of background, b_{image} is the brightness of the pixel. Testings of the screens based on the proposed columnar phosphors show the values $\boldsymbol{k} > 10$ to 20.

A significant electric charge accumulated by standard screens is not completely removed even by metallic (for example, aluminium) coatings 0.1 – 0.5 µm in thickness that are usually formed on the surface of the standard cathodoluminescent screens. This manifests itself in numerous discharges that disturb a stable work of electron devices. The columns are surrounded by gaps coaxial to the columns (see Figs. 7 to 9). The remainder of the substrate area and all other volume of the screen are filled by an electroconductive non-light-emitting medium that has the coefficient of light absorption in respect to the emitting light more than 20 %.

It is to note that the above-mentioned advantages of the columnar screens manifest theyself both in experimental (10x10 mm) and consumer (25x25 or 75x75 mm) sizes of the screens. In other words, the unique parameters of the proposed structure do not depend on the sizes.

Changes of cross-sectional sizes of the light-emitting elements have been studied in respect to characteristics of the screens in general. At the cross-sectional size of the light-emitting elements about 1 µm and the pitch distance about 2 µm a light-emitting structure contained more than $2.5.10^7$ cm^{-2} light-emitting elements has been prepared. The parameters are superior in resolution respectively to all known screens. It has been also found that the columnar structures with pitches 20 µm, at a total number of the columns $2.5.10^5$ cm^{-2}, can have important applications as screens of electron-beam devices and of transducers.

The procedure for filling of the gaps around the columns with the electroconductive non-light-emitting medium consists in a dipping of the columnar structure into a melt of suitable oxides and/or sulphides. Another approach consists in impregnation of columnar structures in low-melting-point compounds. As such, not only oxides like B_2O_3 (melting point 450°C), V_2O_5 (melting point 670°C), CdO (826°C), PbO_2 (290°C), Bi_2O_3 (817°C), but also sulphides SnS (882°C), Sb_2S_3 (550°C) were used. In addition, metallic eutectics like Cd-Bi-Pb-Sn (melting point 65°C) and Pb-Sn were tested, too. All the mentioned compositions absorb the light in the spectral subrange 420 to 760 nanometers, therefore it is possible, in the mosaic columnar

structure, to increase significantly the contrast value owing to an increased absorption of the side emission of the columns and of an external light passing through the transparent substrate.

It was studied an influence of the electroconductive medium on the luminescent properties of the screen formed by the mosaic columnar structure. In the case of the filling of the gaps between the columns by the eutectic metallic phase Cd-Bi-Pb-Sn, the resistivity of the filling phase was 1 to 20 Ohm.cm at the value of the optical absorption > 10^5 cm^{-1}. At the ratio of the substrate area, coated by the columns, to the area of the filling medium 5:1, the coefficient of light reflection from the front surface of the screen is 20%, while a similar columnar structure, that was not filled by the electroconductive medium, reflects 45 to 60% of incident light.

Relationships between the height of the columns and the height level of the light-absorbing phase were not studied. In some preliminary experiments, the relationship was 2:1. Even such a value provided run-off the electron current densities 1 to 10 A/cm^2.

The columnar elements of the mosaic screen can have an additional coating by metallic (Al or Ag) mirror transparent for electron beams with energies > 5 keV.

REFERENCES

1. G.W.Berskstresser and C.D.Brandle, Cathode ray tube with single crystal targets, European Patent Application 232586, Cl. H01 J 29/26 (1987).

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3. B. Cockayne, Cathode ray tube phosphor layers, European Patent Application 062993, Cl. H01 J 29/20 (1982).

4. M. Kakuki, Fluorescent screen of electron tube, Japanese Patent 55088245, Cl. H01 J 29/20 (1980).

CLAIMS

1. A cathodoluminescent mosaic screen on a light-transparent substrate that (screen) contains light-emitting, light-guiding, dielectric, and electroconductive light-absorbing components, the light-emitting components being implemented as columnar crystals, **wherein** each column is surrounded by a gap coaxial to the column, the gaps are filled by an electroconductive non-light-emitting medium.

2. The screen according to the claim 1 **wherein** outer butt-ends of the columns are coated by a light-emitting luminescent layer whose thickness is smaller than height of the columns for at least an order of magnitude.

3. The screen according to the claim 2 **wherein** the luminescent layer is epitaxial in respect to the columns.

4. A method for preparation of luminescent screens consisting of single-crystalline columns on substrates by vapor deposition of luminescent material **wherein** an intermediate substance forming a liquid phase at the crystallization temperature, other than the luminescent material, is firstly deposited on the substrate and, then, the luminescent material is deposited on such a substrate.

5. The method according to the claim 4 **wherein** the thickness of the intermediate substance is more than 10 nanometers and smaller than 1 micrometer.

6. The method according to the claim 4 **wherein** the liquid phase is formed at a contact interaction of the intermediate substance with the substrate.

7. The method according to any of claims 4 or 5 **wherein** the intermediate substance is formed by more than one chemical elements.

8. The method according to the claim 7 **wherein** at least one of the chemical element is operating as a luminescent activator or co-activator.

9. The method according to the claim 4 **wherein** a microrelief of inhomogenities in structure and/or in chemical composition is created on the substrate.

10. The method according to the claim 9 **wherein** the inhomogenities are of a regular character.

11. The method according to the claim 10 **wherein** the inhomogenities have crystallographically-symmetric character.

12. The method according to the claim of any of the claims 4 or 8 **wherein** the activator or co-activator is introduced into the luminescent material by means of ion implantation.

13. The method according to the claim 11 **wherein** the luminescent material is coated by a thin layer of a material transparent for passing through it of electrons.

14. The method according to the claim 13 **wherein** diamond or diamond-like material serve as the transparent material.

An Abstract

A cathodoluminescent mosaic screen on a light-transparent substrate wherin the light-emitting components of the screen are implemented as light-guiding single-crystalline columns. A method for preparation of the screen by vapor deposition of the luminescent material onto the substrate coated by a localized liquid phase has been proposed.

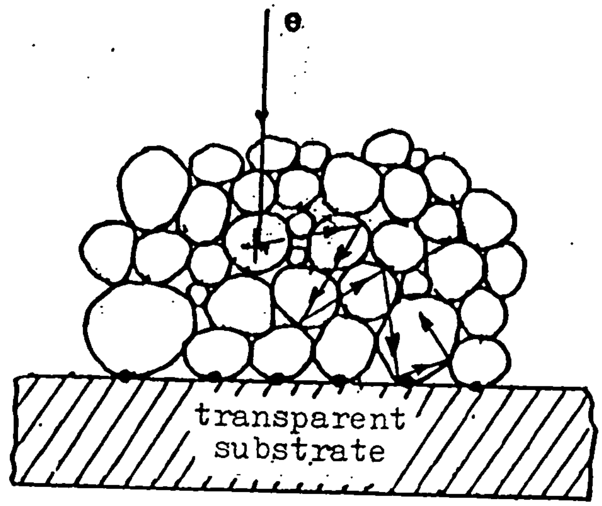


Fig. 1.

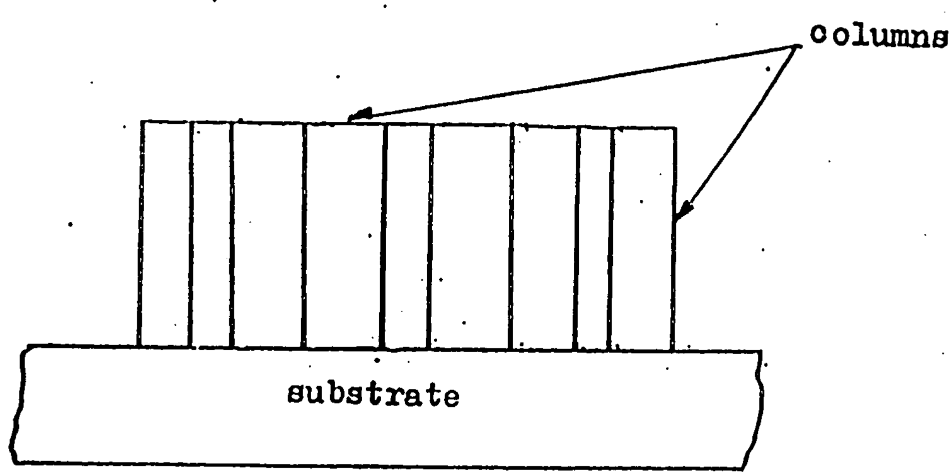
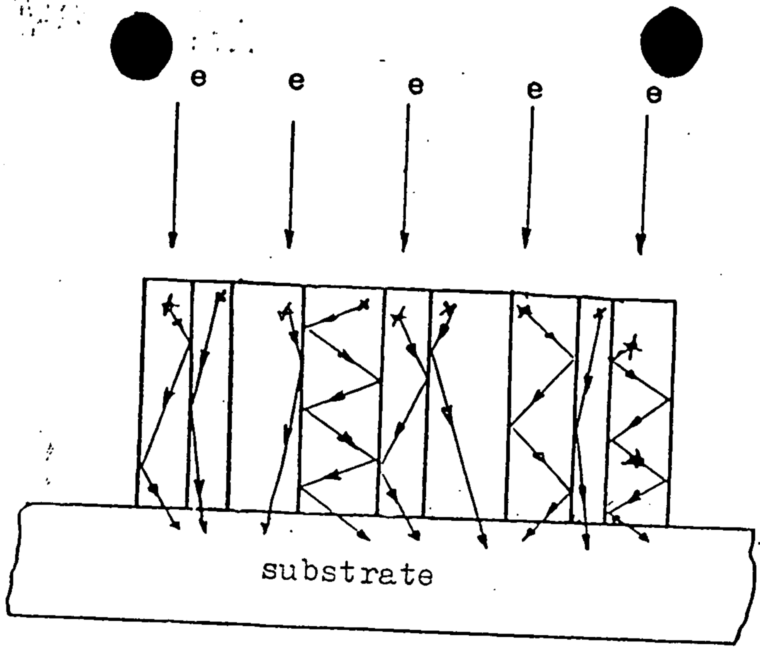


Fig. 2.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e
substrate

Fig. 3.

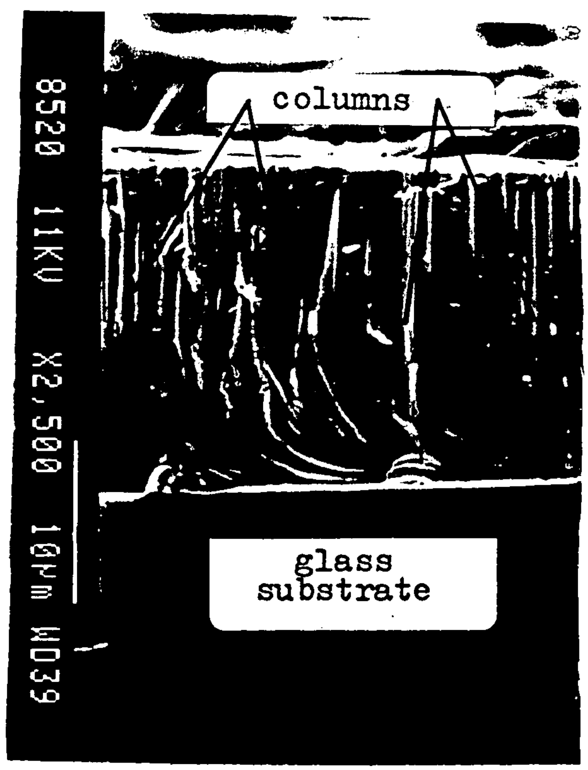
columns
glass substrate
8520 11KV X2,500 10µm WD39

Fig. 4.

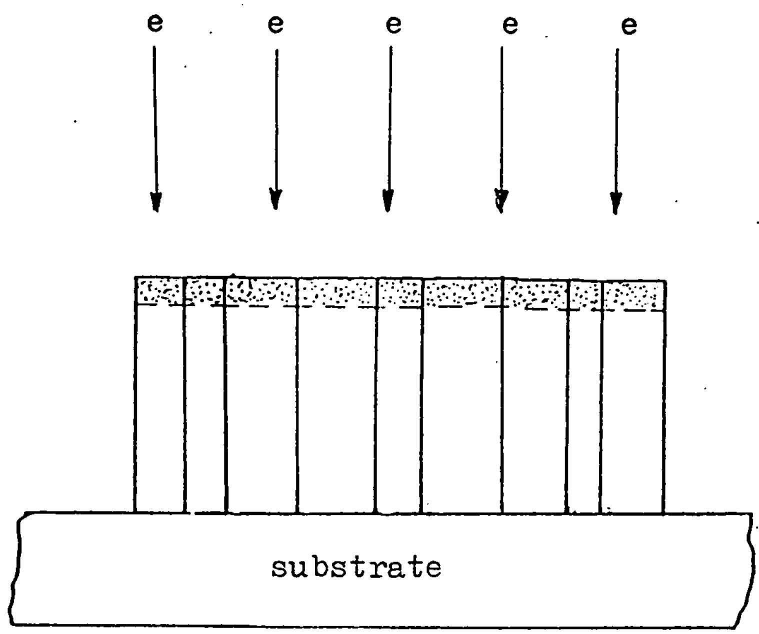
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Fig. 5.

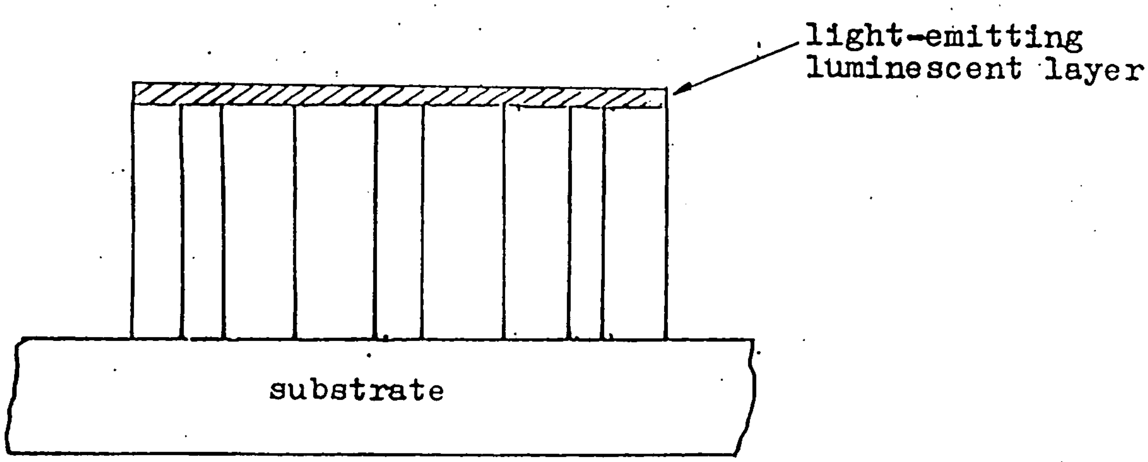
light-emitting
luminescent layer
substrate

Fig. 6.

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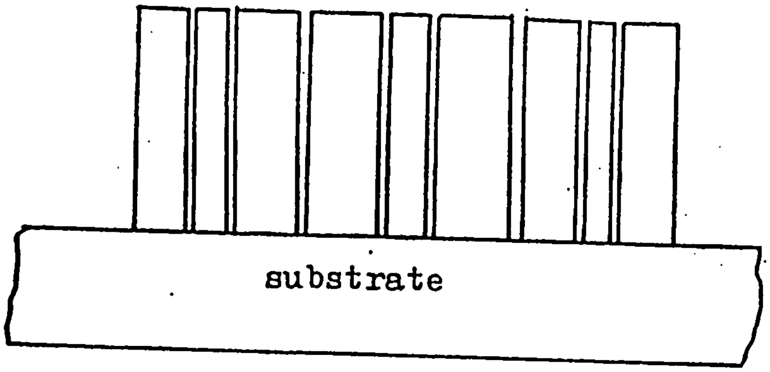

Fig. 7.

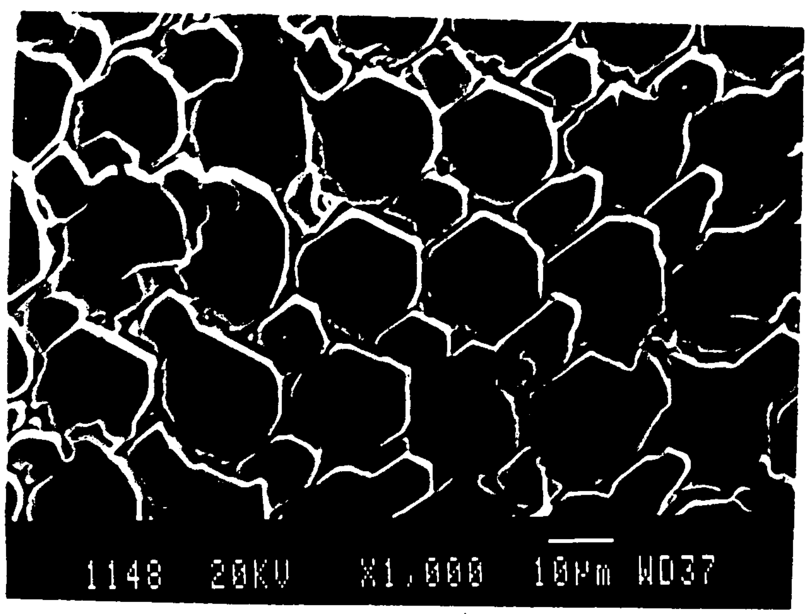

Fig. 8.

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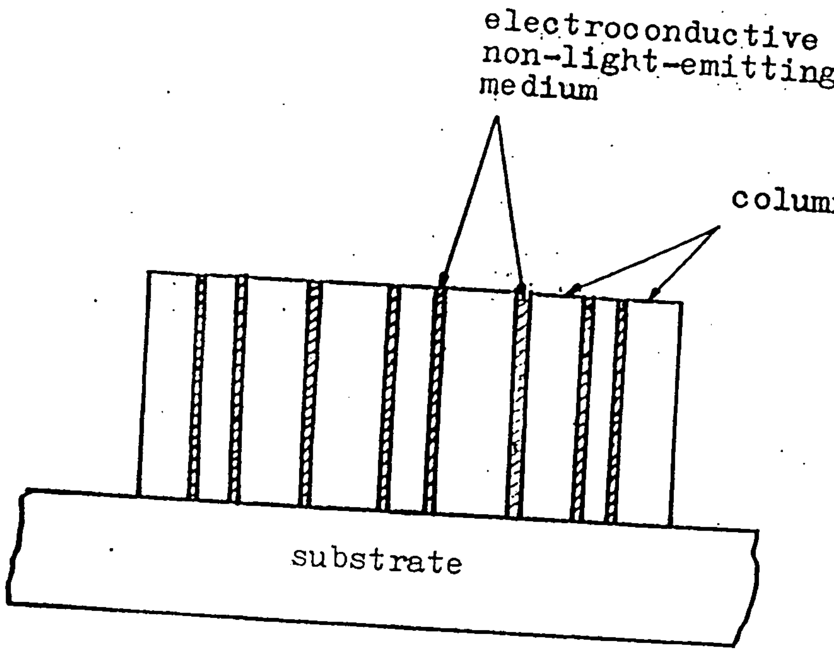

Fig. 9.

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PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference -	**FOR FUTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416
International application No PCT/RU 98/00347	International filing date (day/month/year) 26 October 1998 (26.10.98)	Priority date (day/month/year) 27 October 1997 (27.10.97) 31 December 1997(31.12.97)
International Patent Classification (IPC) or national classification and IPC		H01J 29/18, H01J 9/22

Applicant

GIVARGISOV Evgeny Invievich et al.

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant accoding to Article 36

2. This Report consists of a total of 3 sheets, including this cover sheet.

[X] This report is also accompanied by ANNEXES, i.e., sheets of the description, claimes and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70/16 and Section 607 of the Administrative Instructions under PCT).

These annexes consist of a total of 9 sheets

3. This report contains indications relating to the following items:

- I [X] Basis of the report
- II [ ] Priority
- III [ ] Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- IV [ ] Lack of unity of invention
- V [X] Reasoned statement under Articl 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI [ ] Certain documents cited
- VII [ ] Certain defects in the international application
- VIII [ ] Certain observations on the international application

Date of submission of the demand: 24 May 1999 (24.05.99)	Date of completion of this report: 24 February 2000 (24.02.2000)
Name and mailing address of the IPEA/ RU Federal institut of industrial property Russia, 121858,Moscow,Berezhkovskaya nab., 30-1 Facsimile No.	Authorized officer G.Tarakanova Telephone No 240-2591

Form PCT/IPEA/409 (cover sheet)(July 1998)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No
PCT/RU 98/00347

1. Basis of the report

1. With regard to the **elements** of the international application:*

- [ ] the international application as originally filed
- [x] the description:
  - pages ______, as originally filed
  - pages ______, filed with the demand
  - pages 1-7, filed with the letter of 17 January 2000
- [x] the claims:
  - pages ______, as originally filed
  - pages ______, as amended (together with any statement) under Article 19
  - pages ______, filed with the demand
  - pages 8-9, filed with the letter of 17 January 2000
- [ ] the drawings:
  - pages ______, as originally filed
  - pages ______, filed with the demand
  - pages ______, filed with the letter of ______
- [ ] the sequence listing part of the description:
  - pages ______, as originally filed
  - pages ______, filed with the demand
  - pages ______, filed with the letter of ______

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language ______ which is:

- [ ] the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).
- [ ] the language of publication of the international application (under Rule 48.3 (b)).
- [ ] the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- [ ] contained in the international application in written form.
- [ ] filed together with the international application in computer readable form.
- [ ] furnished subsequently to this Authority in written form
- [ ] furnished subsequently to this Authority in computer form.
- [ ] The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed been furnished.
- [ ] The statement that the information recorded in computer readable form is identical to the sequence listing has been furnished.

4. [ ] The amendments have resulted in the cancellation of:
   - [ ] the description, pages ______
   - [ ] the claims, Nos. ______
   - [ ] the drawings, sheets/fig ______

5. [ ] This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Bof (Rule 70.2(c)).**

* *Replacement sheets which have been furnished to the receiving Office in response to an iinvitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*

** *Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.*

INTERNATIONALPRELIMINARY EXAMINATION REPORT

International application No
PCT/RU 98/00347

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicabillity; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-15	YES
	Claims		NO
Inventive step (IS)	Claims	1-15	YES
	Claims		NO
Industrial applicability (IA)	Claims	1-15	YES
	Claims		NO

2. Citations and explanations (Rule 70.7)

Claims 1-3 meet the criteria of novelty and inventive step since the documents cited in search report don't disclose cathodoluminescent mosaic screen with the light-emitting components implemented as columnar crystals, wherein each column is surrounded by a gap coaxial to the column, all the gaps are filled by an electroconductive non-light-emitting medium that has a coefficient of light absorption in respect to the emittihg light more 20%.

Claims 4-14 meet the criteria of novelty and inventive step since the documents cited in search report don't disclose a method for preparation of luminescent screens wherein an intermediate substance forming a liquid phase at the crystallization temperature, other than the luminescent material, is firstly deposited on the substrat and, then, the luminescent material is deposited on such a substrate.

Claims 1-14 meet the criterion of industrial applicability.

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FIELD OF THE INVENTION

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~~PRIOR ART~~

The existing luminescent screens are produced, as a rule, in the shape of crystalline films that are prepared, for example, by deposition from a vapor phase onto smooth, for example, glass substrate.

For the deposition, techniques of evaporation of materials in vacuum, of sublimation, of chemical transport, of cathode sputtering, etc, are used.

In all the techniques, the nucleation of the crystalline luminescent materials (phosphors) occurs in a non-controlling manner, homogenously or heterogeneously, on a smooth structure-less substrate . At that case, the phosphors are usually a collection of tiny (micron and/or submicron) crystalline grains, usually isometric, approximately spherical shape superposed one onto another (Fig. 1). In such a system, the light generated in a crystalline grain (i.e., designated by a cross) is repeatedly scattered in the labyrinth of surrounding phosphor grains. This phenomenon deteriorates the resolution of the screen.

One more problem relates to the fact that in the film screen, consisting of the crystalline grains, do not all the space is filled by the phosphor. This decreases the effectivity of the screen and deteriorates its thermo- and electroconductivity.

In addition, such screens have a bad adgesion to substrates because the approximately-spherical crystalline grains have only point contacts with the substrates.

In EP-A 232586 ~~the patent [1],~~ single-crystalline (plate-like or epitaxial-layer) materials are used as phosphors. This improves reproducibility of characteristics of the screen and increases its effectivity (the ratio of the light energy to the energy expended for the light excitation). However, at such a case, the emitting light propagates along the plate (or along the epitaxial layer) of the phosphor; this deteriorates the resolution and the effectivity of the screen.

EP-A170310 ~~Another patent [2]~~ supposes localized deposition of a phosphor from a diluted solution or suspension by spinning into holes, side walls of the holes being metallized in order to exclude penetration of the light into neighbor areas of the luminescent scren. However, at this case,

contrast of the image is increased for only 50%; in other words, scattering of the light along the luminescent screen is not excluded.

These drawbacks can be eliminated if the luminescent screen is made of columnar crystallites that have elongated shape whose elongation direction is approximately perpendicular to the plane of the screen. Such an idea is realized in the design described in ~~the patent [3].~~ EP-0622993 At such a case the light excitated at columnar crystallites of the phosphor propagates in the elongation direction of the crystallites, the crystallites being acting as light-guides. However, the method for preparation of such screens by melt crystallization is not suitable for many practically-important cases, e.g., for thin (0.1 - 1 micrometer thickness) flat luminescent screen used in field-emission displays.

In ~~the patent [4],~~ JP 55086245 a screen with columnar crystals has been proposed where an insert of non-luminous black material adjacent to the columnar crystals was placed. Such an insert is able to increase an image contrast of the columns that are directly adjacent to the insert, while other columns that are not adjacent (are not contacted) to the insert are not able to increase their contrast. In addition, ~~patent [4]~~ JP 55086245 does not give a method for preparation of such a screen.

In this invention, a more optimized design of the screen is proposed. In addition, a technology for preparation of the screen is proposed.

SUMMARY OF THE INVENTION

A screen with columnar structure is proposed where each column is surrounded by a gap coaxial to the column, the gaps are filled by an electroconductive non-light-emitting medium. Outer butt-ends of the columns are coated by a light-emitting luminescent layer, thickness of the layer being smaller than height of the columns for at least one order of magnitude. The luminescent layer can be epitaxial in respect to the columns.

A method for preparation of the luminscent screens is proposed in this invention, too. The method consists in vapor deposition of the luminescent material where an intermediate substance, that is other than the luminescent material and that forms a liquid phase at the crystallization temperature, is firstly deposited on the substrate. After that, the luminescent material is deposited on such a substrate. Thickness of the intermediate substance is more than 10 nanometers and smaller than 1 micrometer. The liquid phase is formed at a contact interaction of the intermediate substance with the substrate.

The intermediate substance is formed by more than one chemical elements. At least one of the chemical element is operating as an luminescent activator or co-activator. The activator or co-activator is introduced into the luminescent material by means of ion implantation.

A microrelief of inhomogenities in structure and/or chemical composition is created on the substrate, the inhomogenities being of regular character, in particular, of crystallographically-symmetric character.IPEA/RU

The luminescent material is coated by a thin layer of a material that is transparent for electrons. In particular, diamond or diamond-like material serve as the transparent material.

A BRIEF DESCRIPTION OF THE FIGURES

Fig. 1. A scheme of a standard cathodoluminescent screen that is formed by a film of approximately isometric crystalline grain.

Fig.2. A scheme of a cathodoluminescent screen formed by a film, that consists of columns approximately perpendicular to substrate.

Fig. 3. A scheme of propagation of light beams in the film shown in Fig. 2.

Fig. 4. A SEM micrograph of a cleavage cross-section of a continuous film consisting of the columns.

Fig. 5. A scheme of the cathodoluminescent screen with columnar structure that is bombarded by electrons. The shaded upper parts of the columns show level to which the electrons penetrate and where the light is excited.

Fig. 6. A scheme of the cathodoluminescent screen. The upper butt-ends of the screen are coated by a light-emitting luminescent layer.

Fig. 7. A scheme of the cathodoluminescent screen formed of columns with gaps between them.

Fig. 8. A SEM micrograph of the film that consists of columns with gaps between them (top view). The mosaic structure of the screen is seen.

Fig. 9. A scheme of the cathodoluminescent screen shown in Figs. 7 and 8. The gaps are filled with an electroconductive non-emitting medium.

Dal

~~BEST VERSION FOR THE REALIZATION OF THE INVENTION~~

The cathodoluminescent screen with columnar structure, as it was proposed at the prior art, is illustrated in Figs. 2 and 3.

The cathodoluminescent screen, as it is proposed here, is illustrated in Figs. 4 to 9.

Typical height of the columns, as it is shown in Fig. 4, is about 5 micrometers. Typical height-to-diameter ratio of the columns ranges from 1:1 to 100:1.

An accelerated electron beam from a flat cathode, as it is usually considered in field-emission displays, is incident on the screen and penetrates into a surface layer (Fig. 5). At typical acceleration voltages of the field-emission displays (for example, 1 to 3 kV) the penetration thickness is about 100 nanometers (shown schematically in Fig. 5 as a shadowed layer). Accordingly, it is proposed to implement the screen as a columnar structure coated by a light-emitting luminescent layer (shown in Fig. 6).

The columns are surrounded by gaps ("trenches") coaxial to the columns. An elongated cross-section scheme of the columnar structure is shown in Fig. 7. A corresponding scanning electron micrograph of the screen (top-view) is shown in Fig. 8. As is seen, the columns are

surrounded by gaps ("trenches"). The gaps are filled by an electroconductive non-light-emitting medium has the coefficient of light absorption in respect to the emitting light more than 20%. A scheme of the filled screen is shown in Fig. 9. The filling ensures a conductivity of the screen and, in such a way, excludes charging phenomena when the luminescent screen is working in a cathodoluminescent mode.

These screens are featured by some advantages, especially in respect to low-voltage field-emission displays.

1. By a high light and energetic output that is caused by its design. Owing to the total internal reflection from the walls of the columns, a light-guide effect takes place: the light propagates preferentially along the columns, do not passing beyond columns and do not passing into neighbour columns.

2. By a low light scattering during the light propagation along the columns. This determines a high resolution of the design. It is equal to the number of the light-emitting components per a length unit.

3. By a high adgesion to the transparent substrate, to which the columns are fixed by their butt-ends, i.e., the light-emitting components contact to the substrate by a large area. This is especially important for diode-type field-emission displays where large gradients of the electric field are able to break screen particles off the substrate.

The advantages of the cathodoluminescent screens having the columnar structure are realized here by a proposed technology for their production. The technology is based on chemical or physical vapor deposition, a participation of a liquid phase in the deposition process being of principal importance. An effectivity of the technology is illustrated in Fig. 4 where the columnar structure of the luminescent material cadmium sulphide is shown.

It is to underline principal idea of the proposed design of the cathodoluminscent screen: the propagation direction of light in each columnar component is paraxial (parallel) to the direction of the primary electron beam, that excites the light (see Fig. 3), whereas in the known (standard) screens, formed by superposition of approximately-isometric grains, the light excited by the cathodoluminescence can propagate not only paraxially with the electron beam but also perpendicularly to it, or in any arbitrary direction in respect to the electron beam (see Fig. 1).

As the design of the columnar screen was realized and used in concrete electron devices, some not-evident its advantages were found.

(a) Luminescence brightness of different grains (columns in this case) becomes more uniform. In the standard cathodoluminescent screens, the brightness of various grains differs significantly (up to 50% at distances 25-30 micrometers) due to differences in sizes of emitting grains; this deteriorates transfer and fixation of qualitative images.

(b) Electrical and heat power dissipation by the columnar phosphors increases significantly (5 to 10 times) in comparison with the standard cathodoluminescent screens.

(c) The "burning out" of the columnar screens at an unexpected switching off the electron beam scanning is practically eliminated. In the standard cathodoluminescent screens the power sufficient for irreversable burning out of the screens is usually 0.1 W/element (here the element is an image element, i.e., a pixel), whereas preliminary testings of the proposed columnar screen indicate to increase of the parameter up to 1 W/element (here the element is a column).

(d) The background image contrast at an illumination with intensive light sources (sun, electric lamp, etc) is increased. Standard cathodoluminescent screens have the contrast value $\boldsymbol{k} = b_{image}/b < 5$, where b is the brightness of background, b_{image} is the brightness of the pixel. Testings of the screens based on the proposed columnar phosphors show the values $\boldsymbol{k} > 10$ to 20.

A significant electric charge accumulated by standard screens is not completely removed even by metallic (for example, aluminium) coatings 0.1 – 0.5 μm in thickness that are usually formed on the surface of the standard cathodoluminescent screens. This manifests itself in numerous discharges that disturb a stable work of electron devices. The columns are surrounded by gaps coaxial to the columns (see Figs. 7 to 9). The remainder of the substrate area and all other volume of the screen are filled by an electroconductive non-light-emitting medium that has the coefficient of light absorption in respect to the emitting light more than 20 %.

It is to note that the above-mentioned advantages of the columnar screens manifest theyself both in experimental (10x10 mm) and consumer (25x25 or 75x75 mm) sizes of the screens. In other words, the unique parameters of the proposed structure do not depend on the sizes.

Changes of cross-sectional sizes of the light-emitting elements have been studied in respect to characteristics of the screens in general. At the cross-sectional size of the light-emitting elements about 1 μm and the pitch distance about 2 μm a light-emitting structure contained more than $2.5.10^{7}$ cm^{-2} light-emitting elements has been prepared. The parameters are superior in resolution respectively to all known screens. It has been also found that the columnar structures with pitches 20 μm, at a total number of the columns $2.5.10^{5}$ cm^{-2}, can have important applications as screens of electron-beam devices and of transducers.

The procedure for filling of the gaps around the columns with the electroconductive non-light-emitting medium consists in a dipping of the columnar structure into a melt of suitable oxides and/or sulphides. Another approach consists in impregnation of columnar structures in low-melting-point compounds. As such, not only oxides like B_2O_3 (melting point 450°C), V_2O_5 (melting point 670°C), CdO (826°C), PbO_2 (290°C), Bi_2O_3 (817°C), but also sulphides SnS (882°C), Sb_2S_3 (550°C) were used. In addition, metallic eutectics like Cd-Bi-Pb-Sn (melting point 65°C) and Pb-Sn were tested, too. All the mentioned compositions absorb the light in the spectral subrange 420 to 760 nanometers, therefore it is possible, in the mosaic columnar

structure, to increase significantly the contrast value owing to an increased absorption of the side emission of the columns and of an external light passing through the transparent substrate.

It was studied an influence of the electroconductive medium on the luminescent properties of the screen formed by the mosaic columnar structure. In the case of the filling of the gaps between the columns by the eutectic metallic phase Cd-Bi-Pb-Sn, the resistivity of the filling phase was 1 to 20 Ohm.cm at the value of the optical absorption > 10^5 cm^{-1}. At the ratio of the substrate area, coated by the columns, to the area of the filling medium 5:1, the coefficient of light reflection from the front surface of the screen is 20%, while a similar columnar structure, that was not filled by the electroconductive medium, reflects 45 to 60% of incident light.

Relationships between the height of the columns and the height level of the light-absorbing phase were not studied. In some preliminary experiments, the relationship was 2:1. Even such a value provided run-off the electron current densities 1 to 10 A/cm^2.

The columnar elements of the mosaic screen can have an additional coating by metallic (Al or Ag) mirror transparent for electron beams with energies > 5 keV.

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CLAIMS

WHAT IS CLAIMED IS

1. A cathodoluminescent mosaic screen on a light-transparent substrate that (screen) contains light-emitting, light-guiding, dielectric, and electroconductive light-absorbing components, the light-emitting components being implemented as columnar crystals, **wherein** each column is surrounded by a gap coaxial to the column, all the gaps are filled by an electroconductive non-light-emitting medium that has a coeffiecient of light absorption in respect to the emitting light more 20%.

2. The screen according to the claim 1 **wherein** outer butt-ends of the columns are coated by a light-emitting luminescent layer whose thickness is smaller than height of the columns for at least an order of magnitude.

3. The screen according to the claim 2 **wherein** the luminescent layer is epitaxial in respect to the columns.

4. A method for preparation of luminescent screens consisting of single-crystalline columns on substrates by vapor deposition of luminescent material **wherein** an intermediate substance forming a liquid phase at the crystallization temperature, other than the luminescent material, is firstly deposited on the substrate and, then, the luminescent material is deposited on such a substrate.

5. The method according ~~to the~~ claim 4 **wherein** the thickness of the intermediate substance is more than 10 nanometers and smaller than 1 micrometer.

6. The method according to the claim 4 **wherein** the liquid phase is formed at a contact interaction of the intermediate substance with the substrate.

7. The method according to any of claims 4 or 5 **wherein** the intermediate substance is formed by more than one chemical elements.

8. The method according to the claim 7 **wherein** at least one of the chemical element is operating as a luminescent activator or co-activator.

9. The method according to the claim 4 **wherein** a microrelief of inhomogenities in structure and/or in chemical composition is created on the substrate.

10. The method according to the claim 9 **wherein** the inhomogenities are of a regular character.

11. The method according to the claim 10 **wherein** the inhomogenities have crystallographically-symmetric character.

12. The method according to the claim of any of the claims 4 or 8 **wherein** the activator or co-activator is introduced into the luminescent material by means of ion implantation.

13. The method according to the claim 11 wherein the luminescent material is coated by a thin layer of a material transparent for passing through it of electrons.

14. The method according to the claim 13 **wherein** diamond or diamond-like material serve as the transparent material.

ADD a3

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AMENDED SHEET

PATENT COOPERATION TREATY

09/530512

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 5G-98	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. PCT/RU 98/00347	International filing date *(day/month/year)* 26/10/1998	(Earliest) Priority Date *(day/month/year)* 27/10/1997
Applicant GIVARGIZOV, Evgeny Invievich et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.
   [ ] filed together with the international application in computer readable form.
   [ ] furnished subsequently to this Authority in written form.
   [ ] furnished subsequently to this Authority in computer readble form.
   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).
3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**

   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 2

   [X] as suggested by the applicant.
   [ ] because the applicant failed to suggest a figure.
   [ ] because this figure better characterizes the invention.

   [ ] None of the figures.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/RU 98/00347

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01J29/18 H01J9/22

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 004, no. 133 (E-026), 18 September 1980 & JP 55 088249 A (TOSHIBA CORP), 3 July 1980 see abstract ---	1,2
A	US 3 535 138 A (WANMAKER WILLEM LAMBERTUS ET AL) 20 October 1970 see claim 1 ---	5
A	WO 97 19460 A (CANDESCENT TECH CORP) 29 May 1997 see claim 1 ---	1
A	US 5 378 962 A (GRAY HENRY F ET AL) 3 January 1995 see claims 1-5 --- -/--	1

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 March 1999	29/03/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Van den Bulcke, E

1

INTERNATIONAL SEARCH REPORT

International Application No
PCT/RU 98/00347

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	WO 94 18694 A (SILICON VIDEO CORP) 18 August 1994 see claim 46	1
A	WO 95 26037 A (FED CORP) 28 September 1995 see claim 10	14,15
A	US 4 556 620 A (THOMPSON ROBERT P) 3 December 1985 see claim 1	5
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/RU 98/00347

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PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

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NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

United States Patent and Trademark Office
(Box PCT)
Crystal Plaza 2
Washington, DC 20231
ÉTATS-UNIS D'AMÉRIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 02 August 1999 (02.08.99)	
International application No. PCT/RU98/00347	**Applicant's or agent's file reference** 5G-98
International filing date (day/month/year) 26 October 1998 (26.10.98)	**Priority date** (day/month/year) 27 October 1997 (27.10.97)
Applicant GIVARGIZOV, Evgeny Invievich et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

24 May 1999 (24.05.99)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was
[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No.: (41-22) 740.14.35	Authorized officer Beatriz Morariu Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

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NOTIFICATION CONCERNING DOCUMENT TRANSMITTED

To:

Assistant Commissioner for Patents
United States Patent and Trademark Office
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in its capacity as designated Office

Date of mailing (day/month/year) 13 August 1999 (13.08.99)	
International application No. PCT/RU98/00347	**International filing date** (day/month/year) 26 October 1998 (26.10.98)
Applicant GIVARGIZOV, Evgeny Invievich et al	

The International Bureau transmits herewith the following documents and number thereof:

________ cop(ies) of priority document(s) (Rule 17.2(a))

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No.: (41-22) 740.14.35	Authorized officer Beatriz Morariu Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

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NOTIFICATION CONCERNING SUBMISSION OR TRANSMITTAL OF PRIORITY DOCUMENT

(PCT Administrative Instructions, Section 411)

To:

GIVARGIZOV, Evgeny Invievich
ul. Obrucheva, 20-12
Moscow, 117421
FÉDÉRATION DE RUSSIE

Date of mailing (day/month/year) 06 August 1999 (06.08.99)	
Applicant's or agent's file reference 5G-98	**IMPORTANT NOTIFICATION**
International application No. PCT/RU98/00347	International filing date (day/month/year) 26 October 1998 (26.10.98)
International publication date (day/month/year) 06 May 1999 (06.05.99)	Priority date (day/month/year) 27 October 1997 (27.10.97)
Applicant GIVARGIZOV, Evgeny Invievich et al	

1. The applicant is hereby notified of the date of receipt (except where the letters "NR" appear in the right-hand column) by the International Bureau of the priority document(s) relating to the earlier application(s) indicated below. Unless otherwise indicated by an asterisk appearing next to a date of receipt, or by the letters "NR", in the right-hand column, the priority document concerned was submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b).

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3. An **asterisk(*)** appearing next to a date of receipt, in the right-hand column, denotes a priority document submitted or transmitted to the International Bureau but not in compliance with Rule 17.1(a) or (b). In such a case, **the attention of the applicant is directed** to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

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Priority date	Priority application No.	Country or regional Office or PCT receiving Office	Date of receipt of priority document
27 Octo 1997 (27.10.97)	97117737	RU	14 July 1999 (14.07.99)
31 Dece 1997 (31.12.97)	97122024	RU	14 July 1999 (14.07.99)

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No. (41-22) 740.14.35	Authorized officer Beatriz Morariu Telephone No. (41-22) 338.83.38

INTERNATIONAL SEARCH REPORT

International Application No
PCT/RU 98/00347

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01J29/18 H01J9/22

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 004, no. 133 (E-026), 18 September 1980 & JP 55 088249 A (TOSHIBA CORP), 3 July 1980 see abstract	1,2
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A	WO 97 19460 A (CANDESCENT TECH CORP) 29 May 1997 see claim 1	1
A	US 5 378 962 A (GRAY HENRY F ET AL) 3 January 1995 see claims 1-5	1

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 March 1999	29/03/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Van den Bulcke, E

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	WO 94 18694 A (SILICON VIDEO CORP) 18 August 1994 see claim 46	1
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